INIS
Sborník vědeckých prací Vysoké školy báňské – Technické univerzity Ostrava
číslo 1, rok 2008, ročník LI, řada hutnická
článek č. 1364

POROUS ENGINEERING MODEL OF THE STRUCTURE OF CONSTRUCTIONAL SURFACE ELEMENTS

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ABSTRACT: The surface elements are very important part of load-carrying structure of the mechanical body shell construction. Cross-sections of these constructions are most often made as multilateral, suitable inner ribbing, close profiles or classic sandwich shell-type structures etc. Dynamic development of porous materials increases the possibilities of application their as structural materials. For example porous materials can apply in sandwich structures as core of foamed material. Besides the porous materials can be so formed that the surface elements with a structure similar to classic sandwich structure are obtained. Then the outer faces have homogeneous structure and the core between them have required porosity. The perfect solution would be obtained gradual change of porosity of the structure across thickness. In the paper the basic assumptions of the computational model of cross-section of the surface element of this structure are discussed. Mechanical properties of the porous material vary across thickness of the surface element. The elastic lateral buckling and strength of the square plate and cylindrical panel with this model are carried out. In detail the influence of the variation of Poisson's ratio across the thickness of the element.

KEY WORDS: porosity, thin-walled shell, stability, strength of materials

1. INTRODUCTION

The surface elements such as among other things plates, panels are most often applied in the mechanical body shell constructions. That type constructions, for the sake of higher stiffness, enable get lower weight of device keeping the same exploiting properties like deformations and strength. Cross-sections of these constructions are most often made as multilateral, suitable inner ribbing, close profiles. In case of the application steel materials that are made for example with the aid of pressure welding each other suitable shaping sheets. The constructions of aluminum alloys are most often extruded.

In building of the cross-section of the body shell constructions, the attempts to apply classic sandwich shell-type structure are undertaken. Outer supporting faces are made of high-strength materials like steel, aluminum alloys or composites, and are separated by core made of suitable shaping sheets or plastics.

Dynamic development of porous materials increases the possibilities of application their as structural materials. For example porous materials can apply in sandwich structures as core of foamed material. That can be both plastic and metal e.g. aluminum alloys. Some examples of these constructions are presented in Fig.1. Besides the porous materials can be so formed with the aid of compaction and sintering that the surface elements with a structure similar to classic sandwich structure are obtained. Then the outer faces have homogeneous structure and the core between them have required porosity. An example of that structure is presented in Fig.1. The perfect solution would be obtained gradual change of porosity of the structure along thickness and such element apply in supporting constructions of body shell.

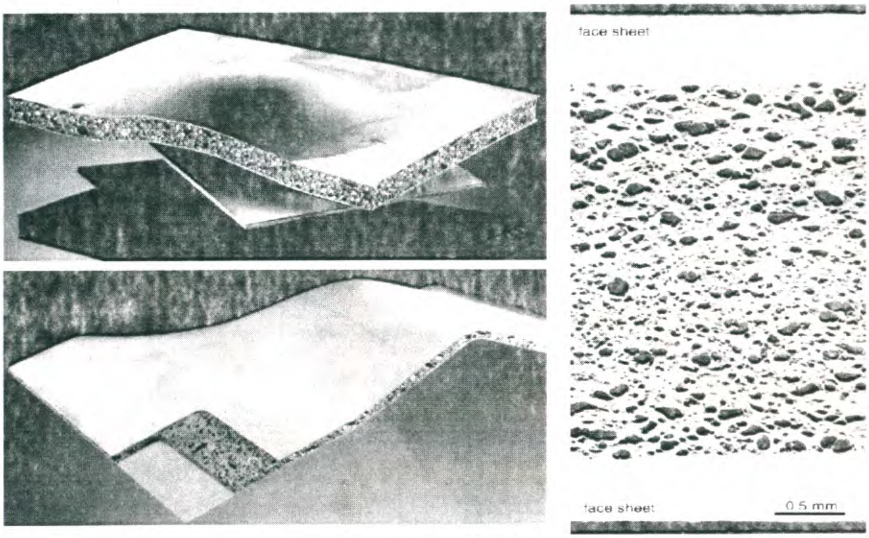

Fig. 1: Sandwich structure made of porous material and cross section of element with variable porosity [1]

2. THE STRUCTURE MODEL OF THE POROUS MATERIALS

The application in building of the mechanical constructions surface elements with a porous structure, require a careful strength and buckling analysis suitable prepared model.
Model of porous material with variable porosity, added in the thin-walled construction are presented in [2]. The model assume that variability of porosity measure is change mechanical properties such as modulus of elasticity, among the thickness according to following relationships:

$$E(z)=E_1[1-e_0\cos(\pi\zeta)], \qquad G(z)=G_1[1-e_0\cos(\pi\zeta)], \tag{1}$$

where:

$e_0=1-(E_0/E_1)=1-(G_0/G_1)$ – porosity ratio
$\zeta=z/t$ – dimensionless coordinate
t-thickness of element
E_0,E_1,G_0,G_1- moduli of elasticity and shear moduli for $\zeta=0$ i $\zeta=\pm 1/2$
$G=E/[2(1+\nu)]$
ν – Poisson's ratio.

Relationships above graphically are presented (continuous line) in Fig.2. In that model is assumed that Poisson's ratio has constant value among the thickness of element. For such âssumptions, researches of such surface elements as rectangular plate and cylindrical panel were carried out and their strength and stability were estimated. The attempts to analysis of possibilities of application in building of the rail vehicles, particularly of the roof of coaches, surface elements with the porous structure are undertaken.
In the next stage of works with surface elements with the porous structure, variability of Poisson's ratio among the thickness is taken into account. Preliminary there is assumed that Poisson's ratio can change in two ways. One of them assumes that variability is according to relationship (1), while another assumes linear change of Poisson's ratio but limit values ν_0 and ν_1 are assumed according to relationship (1). The variability is presented (discontinuous line) in Fig. 2.

3. THE STRENGTH ANALYSES OF THE SURFACE ELEMENTS

Models of surface elements prepared according to assumption above were applied to analysis of rectangular plates and cylindrical panels with diversified porous and shape and load ratio. The behavior of such elements for operating of the following loads: pressure and compression was analyzed. On the basis of results of static strength and stability analysis, influence of variability of Poisson's ratio on the stiffness and critical buckling load was estimated. The analysis was carried out for following data: E_1=205000MPa, v_1=0.3, e_0=0.45; 0.60; 0.75; 0.90; 0.99 and t= 11 mm.

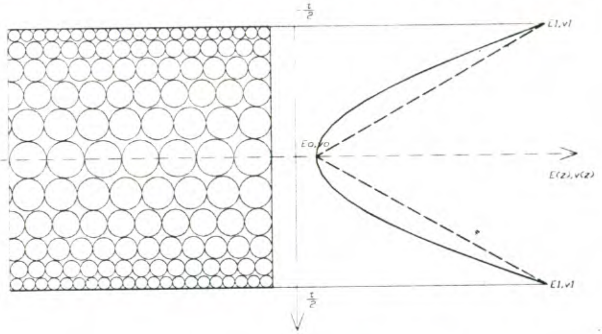

Fig. 2: Scheme of porous shell [2,3]

From static strength analysis of rectangular plate carried a pressure results that stiffness of the plate decreases with the increasing of porosity ratio e_0 and ratio t/a (thickness to length of the side of plate). For each value of e_0 and t/a, plate with constant Poisson's ratio has the highest stiffness. It is about from 0.2% to 1.6% higher than stiffness of plate with nonlinear change and about from 0.5% to 2.3% higher than stiffness of plate with nonlinear change. Only for plate with porosity ratio e_0=0.99 and constant Poisson's ratio, its stiffness is the least.

From static strength analysis of cylindrical panel carried external pressure results that vertical stiffness of panel decreases with the increasing of porosity ratio e_0. Moreover stiffness of panel depends on the angle β and for angle equals 120° the stiffness has minimum. Determined lesser value of stiffness was obtained for panel with bigger shape ratio L/rβ. Variability of stiffness of cylindrical panel according to variability of Poisson's ratio is presented following: for e_0=0.9 stiffness is always the highest for constant Poisson's ratio. With decreasing e_0 and increasing angle β, stiffness of panel with constant Poisson's ratio, to certain value of angle β, is lesser and after overflow that value is bigger than stiffness of panel with linear or nonlinear change of Poisson's ratio. The variability of stiffness of analyzed panels in according to variability of Poisson's ratio varies between 0.8% and 2.5%.

From stability analysis of compressed rectangular plate results that buckling load decreases with the increasing of porosity ratio e_0 and shape ratio a/b but until a/b=1/2 increasing is not large while above that value buckling load violently increases. There is presented in Fig.3. Increasing of load ratio C_{xy} (ratio load of adjacent side of plate) causes decreasing of buckling load. For a given value of porosity ratio, shape ratio a/b and load ratio C_{xy}, buckling load for plate with constant Poisson's ratio is bigger about from 1.6% to 2.3% than for plate with linear change of Poisson's ratio and about from 2,1% to 3,1% for nonlinear change.

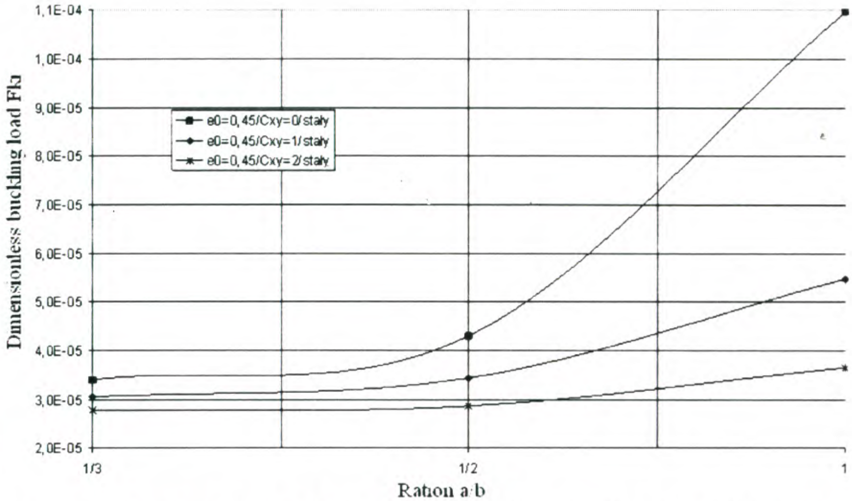

Fig. 3: Dimensionless buckling load for plate in according to ratio a/b, for plate with constant Poisson's ratio and different load ratio C_{xy} (porosity ratio e_0=0.45)

From stability analysis of cylindrical panel carried external pressure results that buckling load decreases with the increasing of porosity ratio e_0 and angle β. The panels with bigger shape ratio $L/r\beta$ have lesser buckling load. Buckling load for panel with constant Poisson's ratio is bigger about from 0.8% to 1.9% than buckling load for panel with linear change of Poisson's ratio and about from 1.1% to 2,6% for nonlinear change. Ratio buckling load for panel with constant Poisson's ratio to buckling load for linear and nonlinear change, changes in according to porosity ratio e_0 and angle β. The bigger e_0 the bigger buckling load ratio. Only for panel with e_0=0.99 occurs certain disturbance of that regularity. For certain identical value of angle appears minimum and then maximum of buckling load ratio. There is presented in Fig.4.

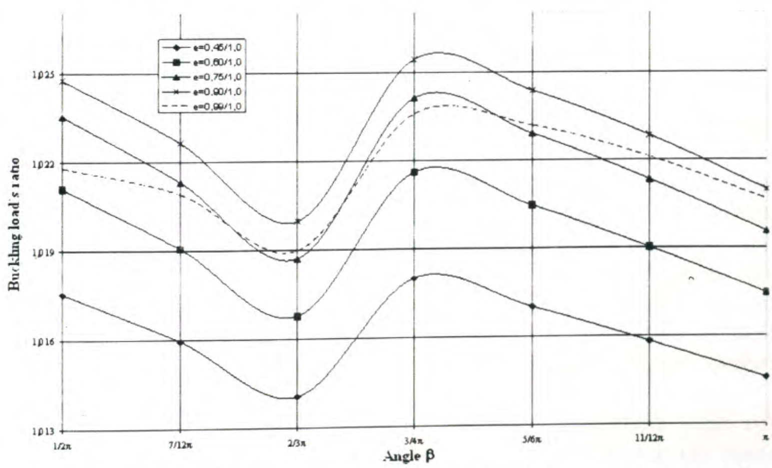

Fig. 4: Ratio buckling load for cylindrical panel with constant Poisson's ratio carried external pressure to nonlinear variable in according to angle β; shape ratio $L/r\beta$=1

From stability analysis of compressed cylindrical panel results that buckling load decreases with the increasing of porosity ratio e_0. Buckling load doesn't depend on angle β and shape ratio $L/r\beta$. Influence of variability of Poisson's ratio on buckling load during panel compression can't interpret unequivocally. Buckling load ratio for panel with constant Poisson's ratio to buckling load for linear and nonlinear variable, oscillates near value of 1, and deviation reaches 3.7%.

4. CONCLUSIONS

From analyses result that decisive influence on basic strength parameters of surface elements with porous structure, such as stiffness and stability, first of all has porosity ratio defined by means of change of mechanical properties such as moduli of elasticity. Influence variability of Poisson's ratio, decided about deformation in transverse direction, is considerably lesser. That influence doesn't cross 4%.

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